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Monthly Performance Report

COLUMBIA GAS SYSTEM

APRIL 1979

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U.S. Department of Energy

National Solar Heating and Cooling Demonstration Program

National Solar Data Program

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MONTHLY PERFORMANCE REPORT
COLUMBIA GAS SYSTEM
APRIL 1979

I. SYSTEM DESCRIPTION

The Columbia Gas System site is a three-story, 25,000 square foot office building in Columbus, Ohio. The solar energy system, which was added to the existing building, is designed to provide 30 percent of the building's total annual thermal energy requirements. The expected annual solar contributions for the three subsystems are 32 percent for space heating, 23 percent for space cooling, and 70 percent for hot water. The collector subsystem is comprised of 44 Honeywell, Inc. north/south tracking, concentrating collectors, facing five degrees east of south. The collectors rotate about an approximate east/west axis to track the daily variation in the sun's elevation angle, and direct the solar radiation toward the absorber tube mounted above the reflectors. The collector array is arranged in 11 rows with a total gross area of 2,978 square feet.

The collector loop heat transfer fluid is a 47 percent solution of Dowtherm SR1. Collected solar energy is transferred to the loads, or to a 5,000-gallon water thermal storage tank via a liquid-to-liquid heat exchanger. Incoming city water is heated for use as domestic hot water on demand, by passing it through another heat exchanger, or preheat coil, located within the water thermal storage tank. A conventional 50-gallon gas-fired hot water heater augments this solar hot water energy from the tank heat exchanger. Solar heated water is also used for space heating and cooling. This thermal energy is supplied either to fin tube heating coils for space heating, or to an absorption chiller for space cooling. When solar energy is insufficient to satisfy heating or cooling demands, thermal energy is provided by an auxiliary gas-fired boiler.

The solar energy system, shown schematically in Figure 1, has six modes of operation which are defined as follows:

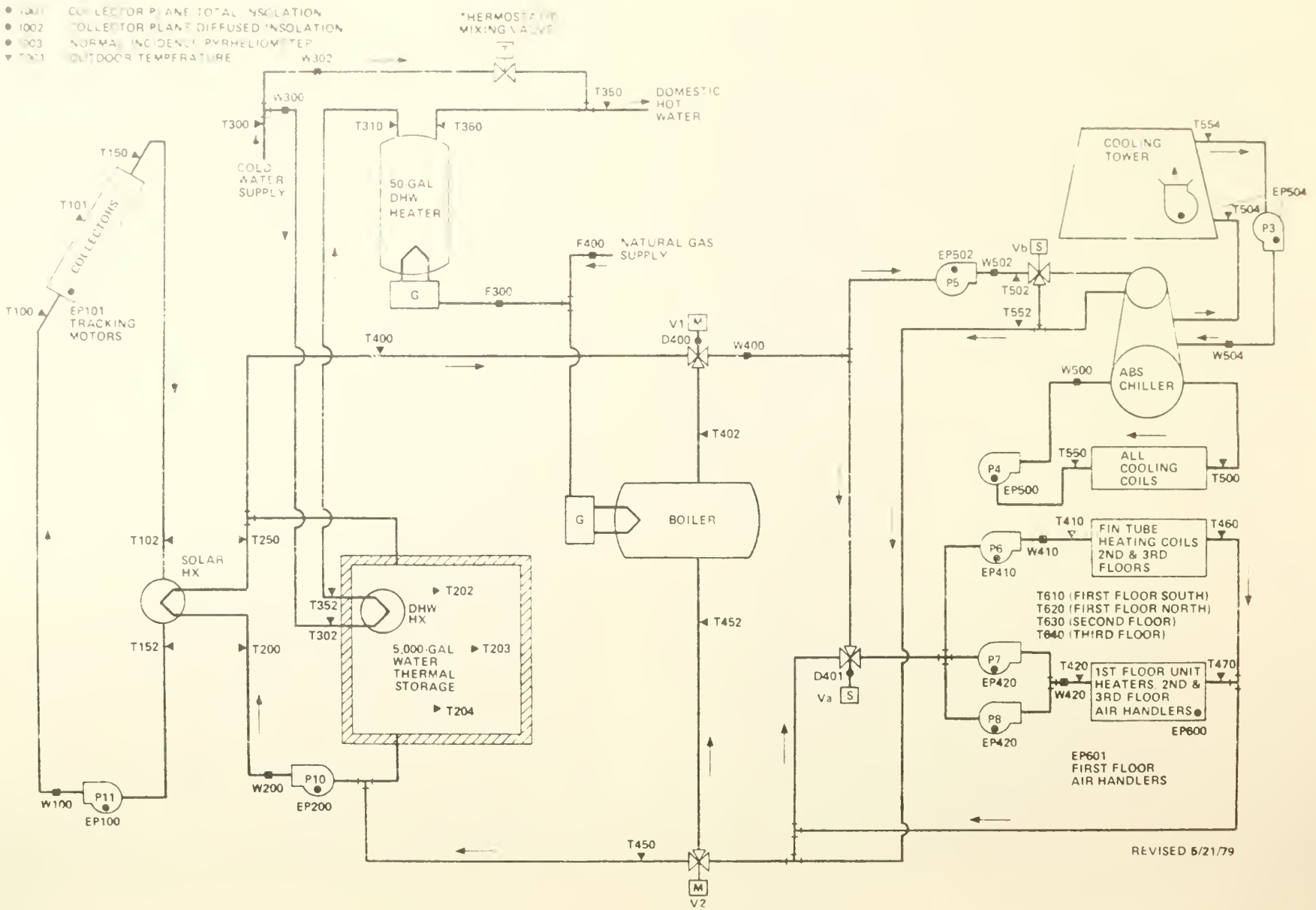

Figure 1. COLUMBIA GAS SYSTEM SOLAR ENERGY SYSTEM SCHEMATIC

Mode 1 - Collectors Tracking: In this mode, the collectors track the sun to collect solar energy. This mode is entered by a four-step process:

1) If measured insolation in the principal plane of the collector is greater than approximately 175 Btu/ft^2-hr, storage tank temperature is less than 210°F, wind speed is less than 20 mph, and collector array outlet temperature is less than 240°F, then collector loop pump P11 is turned on. At this time a closed valve (not shown in Figure 1) allows collector loop flow to bypass the primary side of the collector loop heat exchanger.

2) If flow is detected in the collector loop by a differential pressure switch, the collectors are rotated to the correct tracking position.

3) When the collectors have reached the tracking position, a differential temperature controller checks the collector outlet temperature to determine if it is at least 20°F greater than the storage temperature.

4) If this temperature differential is detected, storage loop pump P10 is turned on to allow flow through the secondary side of the heat exchanger, and the collector loop heat exchanger bypass valve is opened to allow flow through the primary side of that heat exchanger.

The collectors remain in Mode 1 until conditions are met for returning the system to Mode 2 or Mode 3. While in Mode 1, if the collector outlet temperature drops to less than 5°F above the storage tank temperature, then storage loop pump P10 is turned off and the collector loop bypass valve is closed to bypass the primary side of the heat exchanger. The collectors continue to track the sun and collector loop circulation is maintained until the 20°F temperature differential is again met, or until conditions for return to Mode 2 or Mode 3 are met.

Mode 2 - Collectors Stowed: While in Mode 2, the collector reflectors are turned downward toward the roof, or stowed, to prevent collector damage from excessive heat or the elements. This mode is entered from Mode 1 by a two-step process:

1) While in Mode 1, if one or more of five conditions is met, the collectors are placed in the stowed position. These five conditions are: a. wind speed greater than 30 mph for approximately 10 seconds; b. measured insolation in the principal plane of the collector less than approximately 150 Btu/ft^2-hr; c. differential pressure switch senses no flow in the collector loop; d. collector array outlet temperature greater than 252°F; and e. storage tank temperature greater than 220°F.

2) When the collectors have returned to the stowed position, storage loop pump P10 is turned off, the primary side of the collector loop heat exchanger is bypassed, and collector loop pump P11 is turned off.

If the collectors were stowed due to an absence of collector loop flow, manual reset is required before Mode 1 can be reentered. However, if the collectors were stowed for any of the other four conditions, Mode 1 will be reentered automatically whenever its entry conditions are met.

Mode 3 - Collector Emergency Stow: This mode is used to stow the collectors in the event of a power failure. This mode is entered from Mode 1 by a four-step process:

1) If voltage-sensitive relays in all tracking motor phases detect that any phase has dropped below 70 percent rated voltage, an emergency generator is activated.

2) When the generator has reached operating voltage, transfer switches automatically transfer the control system and collector loop pump P11 from the normal building power to the emergency generator.

3) The collector controls cause the collectors to move from the tracking position to the stowed position in four stages (or steps) using power from the emergency generator. During each of the four stages, approximately one-fourth of the total collector array will be stowed.

4) When all collectors have been stowed, the collector loop pump is turned off. The controls are then reset for return to Mode 1 operation when building power is restored.

When building power has been restored, power transfer switches automatically return to building power. After a 10-minute delay, the emergency generator is turned off, and Mode 1 is reentered if its entry conditions are met.

Mode 4 - Solar Energy-to-Space Heating/Cooling: This mode occurs when there is a demand for space heating or cooling and the storage tank temperature exceeds the minimum value suitable for the loads. If summer operation has been manually selected by a master controller, this value is 190°F. If winter operation has been selected, solar energy flow begins at 150°F. These temperature settings are nominal values and can be adjusted by site personnel if desired. When this control temperature setting has been exceeded, the boiler gas supply is immediately shut off and flow continues through the boiler for two minutes to deplete some of the residual energy. The load supply lines are then switched from auxiliary to solar energy. When the storage temperature has dropped by 2°F, Mode 4 is terminated. If storage loop pump P10 is operating while Mode 4 is active, part of the energy supplied to the loads will come directly from the heat exchanger and the balance will come from storage. If this pump is not operating, all the solar energy supplied to the loads originates from storage.

Mode 5 - Collector-to-Storage: This mode occurs while the collectors are operating in Mode 1, but the conditions for Mode 4 entry are not met.

While in this mode, solar energy is routed directly from the collectors to storage via the collector loop heat exchanger. Mode 5 is terminated upon entry to Mode 2, 3 or 4.

Mode 6 - Storage-to-Domestic Hot Water: This mode occurs while a domestic hot water demand is present. When hot water is being used, makeup cold water flows by supply pressure through the hot water preheat coil in the storage tank. This makeup water absorbs stored solar energy as it passes enroute to the conventional hot water heater.

In addition to these six modes, individual collector rows can be stowed if they overheat. Each of the 11 individual collector rows has a separate control system sensor indicating absorber tube temperature. If the temperature of an individual collector row absorber tube exceeds 260°F, that collector row is stowed. When the temperature then drops below 220°F, that collector row resumes tracking. If the collector row overheats a second time, a manual reset is required to restart the individual collector row.

II. PERFORMANCE EVALUATION

The system performance evaluations discussed in this section are based primarily on the analysis of the data presented in the attached computer-generated monthly report. This attached report consists of daily site thermal and energy values for each subsystem, plus environmental data. The performance factors discussed in this report are based upon the definitions contained in NBSIR 76-1137, Thermal Data Requirements and Performance Evaluation Procedures for the National Solar Heating and Cooling Demonstration Program.

A. Introduction

The solar energy system at the Columbia Gas site collected energy on 9 days during April. This was due partially to relatively low insolation, but was also affected by the practice of operating the collector subsystem only on work days. Consequently, solar energy supplied only

3.0 percent of the total system thermal energy load. Domestic hot water was the only active solar energy load, and received 4.17 million Btu of solar energy during the month. Although storage temperatures exceeded the 150°F control set point for heating on several days during the month, no solar energy was used for space heating or cooling. This was due to manual intervention. High storage tank temperatures were maintained for a few days during April by inhibiting circulation to the heating and cooling loads. This was done to simplify analysis of storage thermal losses.

Measurement inaccuracies limited the extent of performance evaluation possible for the domestic hot water subsystem.

B. Weather

April is typically a transitional month in Columbus, with a long-term average outside ambient temperature of 54.3°F and 418 heating-degree days. This month the actual outside ambient temperature average was 51°F and 422 heating-degree days were experienced. The measured insolation in the plane of the pyranometers (five degrees east of south, with a tilt of 40 degrees from the horizontal) averaged 1,123 Btu/ft^2-day, which was significantly less than the expected long-term average of 1,467 Btu/ft^2-day. This reduction in available solar energy was responsible for a decrease in solar energy system performance.

C. System Thermal Performance

Collector - Of the 100.3 million Btu of incident solar energy on the collector array during April, 29.3 million Btu were incident on the array while collection and storage pumps P11 and P10 were operating. The system collected 9.67 million Btu, or 9.6 percent of the total insolation incident on the collector array. This was 33.0 percent of the insolation incident while the pumps were operating. Since these collectors are tracking concentrators, they use only the direct or beam component of solar energy. While pumps P10 and P11 were operating and the collectors were tracking the sun

during April, a total of 25.5 million Btu of direct solar energy was incident on the collector array. Of this incident direct solar energy, 37.9 percent was collected by the array, which agrees closely with the 35.1 percent collected in March. During April, pumps P10 and P11 and the collector tracking motors used a combined total of 0.57 million Btu of electrical energy.

Storage - Of the 9.67 million Btu of solar energy collected, 8.59 million Btu were delivered to the storage tank. Since all collected solar energy during April was routed directly to the storage tank and none was used directly by the heating and cooling loads, the energy to storage could be deducted from the collected solar energy to determine a loss of 1.08 million Btu between the collector array and storage. This loss was 11.2 percent and was due to heat exchanger inefficiency and line losses. A total of 4.17 million Btu of solar energy was extracted from the storage tank to preheat domestic hot water. The net energy in storage increased by 1.03 million Btu during the month. A summary of energy in and out of storage is shown below. The net thermal loss from storage was 3.39 million Btu.

8.59	million Btu	- energy to storage tank
-4.17	million Btu	- energy extracted from storage tank
4.42	million Btu	
-1.03	million Btu	- energy increase in storage tank
3.39	million Btu	- thermal loss from storage tank

Domestic Hot Water Load - The domestic hot water subsystem operated continuously during April. The daily average hot water consumption was 300 gallons for the month. The 6.52 million Btu of energy added to the subsystem were comprised of 4.17 million Btu of solar energy and 1.85 million Btu of auxiliary thermal energy, giving a hot water solar fraction of 77 percent. Hot water was supplied at an average temperature of 116°F and was replaced with cold water at an average temperature of 59°F.

Space Heating Load - Because of the relatively cool ambient temperatures, space heating was required each day during April. The space heating load of 148.7 million Btu was supplied solely by auxiliary thermal energy. In order to provide this auxiliary thermal energy, 239.5 million Btu of natural gas were required. The ratio of auxiliary thermal energy used to natural gas supplied showed a boiler conversion efficiency of 62.1 percent. As previously mentioned, storage temperatures must exceed 150°F before solar energy can be used for space heating. Although storage temperatures exceeded 150°F on several days during April, the space heating loop was manually isolated from the solar energy system and no solar energy was used for space heating.

Space Cooling Load - No solar energy was used for space cooling during the month. In order for solar energy to be used for space cooling, the temperature in the top of the storage tank must be greater than or equal to 190°F to run the absorption chiller. If this temperature is reached, solar energy for space cooling can be supplied directly from the collector array via the heat exchanger, from storage, or from a combination of both. During this month, the top storage temperature exceeded 190°F on April 19 and 20. Total elapsed time for both days was approximately two hours. Auxiliary thermal energy was used to provide 39.6 million Btu of space cooling during the month. The absorption chiller used 88.9 million Btu of auxiliary thermal energy. Calculations indicated 130.5 million Btu of natural gas were required to provide this auxiliary thermal energy. The coefficient of performance of the absorption chiller was 0.45.

D. Observations

The solar energy system showed a noticeable improvement in performance in April, by supplying three percent of the system thermal energy requirement. This is primarily due to a more accurate flow totalizer recently installed in the domestic hot water subsystem. For the previous six months of system operation, the net measure solar contribution was between 0.66 and 1.22 percent, which contrasts to an expected solar contribution of 30 percent. Additional activity is in progress at the site to decrease thermal losses from storage and reduce collector array tracking limitations. As this effort continues, a gradual increase in system performance is anticipated.

As noted in Section A, solar energy was collected on only nine days during April. The collection subsystem was not enabled on nine other days during the month which fell on weekends. This left 12 days during the month when the subsystem was enabled but did not collect energy. Further examination of the data showed that available insolation in the principal plane of the collector was not sufficient to activate collection on 11 of these 12 days. On the remaining one day (April 24), available insolation exceeded 175 Btu/ft^2-hour for 1.5 hours but the pumps and tracking motors were not turned on. This indicates that either the wind speed exceeded 20 mph on each of these days, or the collection loop was disabled.

A problem due to inadvertent flow of hot water through heating coils at the wrong time is adding to the cooling load. For example, when the absorption chiller was operating on April 25 as much as 70°F temperature drop across the T470 and T420 sensors was observed at 17:57 hours with no flow indication on flowmeter W420. This is due to a backflow forced through pumps P6, P7 and P8 and adds appreciably to the total building cooling load. The actual added load is unknown. During the transitional season this problem will not be easily solved. When cooling only is required, the heating coils can be isolated with manual valves and the problem will be eliminated.

E. Energy Savings

The Columbia Gas solar energy system resulted in a savings of 6.94 million Btu of natural gas during the month. This savings is the natural gas equivalent of the 4.17 million Btu of solar energy removed from storage and used to heat domestic hot water. This savings resulted only from the domestic hot water load because no solar energy was used for either heating or cooling. In order to operate the solar energy system, 0.57 million Btu of electrical energy were used to operate the collector tracking motors and pumps.

To allow a direct comparison of natural gas savings with electrical expense, an efficiency of 30 percent was assumed for converting natural gas to electricity and transmitting that energy to the user. This shows that the 0.57 million Btu of electrical energy were equivalent to 1.88 million Btu of

natural gas. Subtracting this from the solar energy fossil fuel savings of 6.94 million Btu gave a net energy savings of 5.05 million Btu of natural gas when compared to a conventional system. Computed cumulative energy savings for October through April were 7.54 million Btu of equivalent fossil energy. However, actual savings may be as much as twice this amount, due to measurement uncertainties in the hot water subsystem.

III. ACTION STATUS

The solar energy system collected energy on nine days during April and is still being refined by site personnel. As this activity continues, the solar energy system will become fully operational and carry a larger portion of the system load. Collector array modifications are in progress to improve tracking accuracy, which will increase the solar energy contribution. Site personnel are also checking the storage tank to determine the source of the high thermal losses. A maintenance visit is planned for May 1 to make adjustments to the hot water instrumentation.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SITE SUMMARY

SITE: COLUMBIA GAS, COLUMBUS, OHIO SOLAR/9999-79/04
REPORT PERIOD: APRIL,1979

SITE/SYSTEM DESCRIPTION:
THE COLUMBIA GAS SOLAR ENERGY SYSTEM PROVIDES HEATING, COOLING AND DOMESTIC HOT WATER FOR A 25,000 SQ FT BUILDING. AUXILIARY HEATING AND COOLING ENERGY IS PROVIDED BY A NATURAL GAS BOILER WHICH FIRES A 100 TON ABSORPTION CHILLER OR FLOWS THROUGH FINNED-TUBE HEATING COILS AS THE LOAD DEMANDS. A SEPARATE DOMESTIC HOT WATER HEATER IS USED. THE COLLECTOR ARRAY CONSISTS OF 44 NORTH-SOUTH TRACKING CONCENTRATORS WITH A TOTAL EFFECTIVE AREA OF 2878 SQ FT. THE COLLECTOR FLUID IS A 47 PERCENT SOLUTION OF DOWTHERM SR1. THE SOLAR ENERGY IS STORED IN A 5000 GALLON THERMAL ENERGY STORAGE TANK.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	100.316	MILLION BTU
	33686	BTU/SQ.FT.
COLLECTED SOLAR ENERGY	9.667	MILLION BTU
	3246	BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	51	DEGREES F
AVERAGE BUILDING TEMPERATURE	73	DEGREES F
BOSS SOLAR CONVERSION EFFICIENCY	0.04	
BOSS OPERATING ENERGY	0.566	MILLION BTU
TOTAL SYSTEM OPERATING ENERGY	58.139	MILLION BTU
TOTAL ENERGY CONSUMED	440.788	MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	6.519	148.654	39.581	196.879 MILLION BTU
SOLAR FRACTION	77	0	0	3 PERCENT
SOLAR ENERGY USED	4.166	0.000	0.000	4.166 MILLION BTU
OPERATING ENERGY	N.A.	31.199	26.374	58.139 MILLION BTU
AUX. THERMAL ENERGY	1.851	148.654	88.950	239.573 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	3.077	239.486	130.456	373.011 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.566 MILLION BTU
FOSSIL SAVINGS	6.943	0.000	0.000	6.943 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 0.347

* DENOTES UNAVAILABLE DATA
@ DENOTES NULL DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT OF THE NATIONAL SOLAR DATA PROGRAM,FEBRUARY 28,1978, SOLAR/0004-78/18

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SITE SUMMARY

SITE: COLUMBIA GAS, COLUMBUS, OHIO — SOLAR/9999-79/04
REPORT PERIOD: APRIL,1979

SITE/SYSTEM DESCRIPTION:
THE COLUMBIA GAS SOLAR ENERGY SYSTEM PROVIDES HEATING, COOLING AND DOMESTIC HOT WATER FOR A 25,000 SQ FT BUILDING. AUXILIARY HEATING AND COOLING ENERGY IS PROVIDED BY A NATURAL GAS BOILER WHICH FIRES A 100 TON ABSORPTION CHILLER OR FLOWS THROUGH FINNED-TUBE HEATING COILS AS THE LOAD DEMANDS. A SEPARATE DOMESTIC HOT WATER HEATER IS USED. THE COLLECTOR ARRAY CONSISTS OF 44 NORTH-SOUTH TRACKING CONCENTRATORS WITH A TOTAL EFFECTIVE AREA OF 2978 SQ FT. THE COLLECTOR FLUID IS A 47 PERCENT SOLUTION OF DOWTHERM SR1. THE SOLAR ENERGY IS STORED IN A 5000 GALLON THERMAL ENERGY STORAGE TANK.

GENERAL SITE DATA:

INCIDENT SOLAR ENERGY	105.833	GIGA JOULES
	382534	KJ/SQ.M.
COLLECTED SOLAR ENERGY	10.199	GIGA JOULES
	36863	KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	11	DEGREES C
AVERAGE BUILDING TEMPERATURE	23	DEGREES C
DOSS SOLAR CONVERSION EFFICIENCY	0.04	
DOSS OPERATING ENERGY	0.598	GIGA JOULES
TOTAL SYSTEM OPERATING ENERGY	61.337	GIGA JOULES
TOTAL ENERGY CONSUMED	465.031	GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	6.878	156.830	41.758	207.707 GIGA JOULES
SOLAR FRACTION	77	0	0	3 PERCENT
SOLAR ENERGY USED	4.395	0.000	0.000	4.395 GIGA JOULES
OPERATING ENERGY	N.A.	32.915	27.824	61.337 GIGA JOULES
AUX. THERMAL ENG	1.953	156.830	93.842	252.750 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	3.246	252.657	137.631	393.527 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	-0.598 GIGA JOULES
FOSSIL SAVINGS	7.325	0.000	0.000	7.325 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 0.347

* DENOTES UNAVAILABLE DATA
@ DENOTES NULL DATA
N.A. DENOTES NOT APPLICABLE DATA

REFERENCE: USER'S GUIDE TO THE MONTHLY PERFORMANCE REPORT OF THE NATIONAL SOLAR DATA PROGRAM,FEBRUARY 28,1978, SOLAR/0004-78/18

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: APRIL,1979

SOLAR/9999-79/04

DAY OF MONTH	INCIDENT SOLAR ENERGY MILLION BTU	AMBIENT TEMP DEG-F	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY
1	0.497	46	0.000	N	0.000	N	0.000
2	2.092	55	0.000	O	0.002	O	0.000
3	2.881	43	0.000	T	0.000	T	0.000
4	0.369	43	0.000		0.001		0.000
5	3.235	47	0.000	A	0.002	A	0.000
6	6.793	32	0.168	P	0.092	P	0.025
7	3.113	34	0.054	P	0.000	P	0.017
8	1.533	49	0.043	L	0.000	L	0.028
9	0.429	39	0.165	I	0.000	I	0.384
10	5.720	44	0.180	C	0.071	C	0.031
11	1.486	49	0.171	A	0.000	A	0.115
12	3.148	67	0.147	E	0.000	E	0.047
13	0.716	60	0.154	L	0.000	L	0.215
14	4.157	53	0.073	E	0.000	E	0.018
15	1.682	46	0.034		0.000		0.020
16	1.565	44	0.097		0.000		0.062
17	4.941	47	0.119		0.049		0.024
18	6.604	51	0.232		0.077		0.035
19	6.456	53	0.288		0.069		0.045
20	5.679	57	0.331		0.059		0.058
21	3.739	64	0.140		0.000		0.037
22	1.826	60	0.102		0.000		0.056
23	2.281	60	0.294		0.003		0.129
24	3.897	67	0.324		0.002		0.083
25	5.076	72	0.291		0.047		0.057
26	0.776	59	0.253		0.000		0.327
27	5.977	52	0.215		0.032		0.036
28	2.587	45	0.063		0.000		0.024
29	5.319	49	0.054		0.000		0.010
30	5.742	52	0.174		0.059		0.030
SUM	100.316	-	4.166	N.A.	0.566	N.A.	-
AVG	3.344	51	0.139	N.A.	0.019	N.A.	0.042
NBS ID	G001	N113			G102		N111

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
COLLECTOR ARRAY PERFORMANCE

SITE: COLUMBIA GAS, COLUMBUS, OHIO SOLAR/9999-79/04
REPORT PERIOD: APRIL,1979

DAY OF MONTH	INCIDENT SOLAR ENERGY MILLION BTU	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU	DAYTIME AMBIENT TEMP DEG F	COLLECTOR ARRAY EFFICIENCY
1	0.497	0.000	0.000	46	0.000
2	2.092	0.000	0.000	62	0.000
3	2.881	0.000	0.000	46	0.000
4	0.369	0.000	0.000	46	0.000
5	3.235	0.000	0.000	48	0.000
6	6.793	4.456	1.316	34	0.194
7	3.113	0.000	0.000	40	0.000
8	1.533	0.000	0.000	55	0.000
9	0.429	0.000	0.000	34	0.000
10	5.720	3.527	1.074	51	0.188
11	1.486	0.000	0.000	45	0.000
12	3.148	0.000	0.000	73	0.000
13	0.716	0.000	0.000	64	0.000
14	4.157	0.000	0.000	61	0.000
15	1.682	0.000	0.000	47	0.000
16	1.565	0.000	0.000	*	0.000
17	4.941	1.761	0.480	54	0.097
18	6.604	4.811	1.853	63	0.281
19	6.456	4.446	1.476	65	0.229
20	5.679	3.790	1.621	*	0.285
21	3.739	0.000	0.000	75	0.000
22	1.826	0.000	0.000	64	0.000
23	2.281	0.000	0.000	*	0.000
24	3.897	0.000	0.000	*	0.000
25	5.076	1.485	0.371	77	0.073
26	0.776	0.000	0.000	61	0.000
27	5.977	1.502	0.471	54	0.079
28	2.587	0.000	0.000	49	0.000
29	5.319	0.000	0.000	55	0.000
30	5.742	3.476	1.005	57	0.175
SUM	100.316	29.252	9.667	-	-
AVG	3.344	0.975	0.322	55	0.096
RESID	G001		G100		N100

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
STORAGE PERFORMANCE

SITE: COLUMBIA GAS, COLUMBUS, OHIO SOLAR/9999-79/04
REPORT PERIOD: APRIL,1979

DAY OF MONTH	ENERGY TO STORAGE MILLION BTU	ENERGY FROM STORAGE MILLION BTU	CHANGE IN STORED ENERGY MILLION BTU	STORAGE AVERAGE TEMP DEG F	STORAGE EFFICIENCY
1	0.000	0.000	-0.097	113	1.000
2	0.000	0.000	-0.174	109	1.000
3	0.000	0.000	-0.097	106	1.000
4	0.000	0.000	-0.124	104	1.000
5	0.000	0.000	-0.198	99	1.000
6	1.145	0.168	1.046	110	1.060
7	0.000	0.054	-0.228	120	1.000
8	0.000	0.043	-0.174	115	1.000
9	0.000	0.165	-0.283	109	1.000
10	0.948	0.180	0.951	118	1.193
11	0.000	0.171	-0.386	125	1.000
12	0.000	0.147	-0.282	116	1.000
13	0.000	0.154	-0.225	110	1.000
14	0.000	0.073	-0.132	105	1.000
15	0.000	0.034	-0.078	103	1.000
16	0.000	0.097	-0.151	100	1.000
17	0.444	0.119	0.469	105	1.325
18	1.755	0.232	1.801	133	1.158
19	1.264	0.288	0.977	168	1.001
20	1.425	0.331	0.159	181	0.343
21	0.000	0.140	-0.390	179	1.000
22	0.000	0.102	-0.311	170	1.000
23	0.000	0.294	-0.532	160	1.000
24	0.000	0.324	-0.389	151	1.000
25	0.298	0.291	-0.031	146	0.871
26	0.000	0.253	-0.510	140	1.000
27	0.388	0.215	0.116	133	0.854
28	0.000	0.063	-0.416	130	1.000
29	0.000	0.054	-0.305	121	1.000
30	0.921	0.174	1.020	131	1.297
SUM	8.589	4.166	1.026	-	-
AVG	0.286	0.139	0.034	127	0.604
NES ID	Q200	Q201	Q202		N108

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
HOT WATER SUBSYSTEM

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: APRIL,1979

SOLAR/0999-79/04

DAY OF MON.	HOT WATER LOAD MILLION BTU	SOLAR FR.OF LOAD PER CENT	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT ENERGY SAVINGS MILLION BTU	FOSSIL ENERGY SAVINGS MILLION BTU	SUP. WAT. TEMP DEG F	HOT WAT. TEMP DEG F	HOT WATER USED GAL
1	*	*	0.000	N	0.011	N	0.019	N	0.000	*	*	*
2	*	*	0.000	O	0.167	O	0.278	O	0.000	*	*	*
3	*	*	0.000	T	0.101	T	0.168	T	0.000	*	*	*
4	*	*	0.000		0.206		0.343		0.000	*	*	*
5	*	*	0.000	A	0.085	A	0.141	A	0.000	*	*	*
6	*	*	0.168	P	0.045	P	0.075	P	0.280	*	*	*
7	0.064	84	0.054	P	0.010	P	0.017	P	0.091	62	94	132
8	0.054	79	0.043	L	0.011	L	0.019	L	0.071	65	91	121
9	0.288	57	0.165	I	0.123	I	0.205	I	0.275	57	116	425
10	0.322	56	0.180	C	0.142	C	0.236	C	0.300	55	124	381
11	0.261	66	0.171	A	0.090	A	0.149	A	0.286	56	119	335
12	0.242	60	0.147	B	0.096	E	0.160	B	0.244	56	118	334
13	0.166	93	0.154	L	0.011	L	0.019	L	0.257	54	99	379
14	0.084	87	0.073	E	0.011	E	0.019	E	0.122	59	93	230
15	0.045	75	0.034		0.011		0.019		0.056	66	91	134
16	0.163	59	0.097		0.093		0.155		0.161	59	107	330
17	0.256	47	0.119		0.137		0.228		0.199	57	122	320
18	0.307	76	0.232		0.075		0.125		0.387	57	123	364
19	0.307	94	0.288		0.019		0.032		0.480	58	133	327
20	0.508	65	0.331		0.163		0.271		0.551	58	141	342
21	0.140	100	0.140		0.000		0.000		0.233	59	132	161
22	0.102	100	0.102		0.000		0.000		0.170	58	134	129
23	0.294	100	0.294		0.000		0.000		0.490	57	132	401
24	0.328	99	0.324		0.004		0.007		0.540	57	125	486
25	0.318	91	0.291		0.033		0.055		0.484	56	125	433
26	0.294	86	0.253		0.041		0.068		0.422	58	122	427
27	0.248	87	0.215		0.032		0.053		0.358	61	116	396
28	0.074	85	0.063		0.011		0.019		0.104	67	105	132
29	0.065	84	0.054		0.011		0.018		0.090	66	100	130
30	0.283	64	0.174		0.114		0.182		0.290	62	113	356
SUM	6.519	-	4.166	N.A.	1.851	N.A.	3.077	N.A.	6.943	-	-	9004
AVG	0.217	77	0.139	N.A.	0.062	N.A.	0.103	N.A.	0.231	59	116	300
NBS	Q302	N300	Q300	Q303	Q301	Q305	Q306	Q311	Q313	N305	N307	N308

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SPACE HEATING SUBSYSTEM

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: APRIL,1979

SOLAR/9999-79/04

DAY OF MON.	SPACE HEATING LOAD MILLION BTU	SOLAR FR.OF LOAD PCT	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT ENERGY SAVINGS MILLION BTU	FOSSIL ENERGY SAVINGS MILLION BTU	BLDG TEMP DEG. F	AMB TEMP DEG. F
1	4.437	0	0.000	0.990	4.437	N	7.415	N	0.000	71	46
2	4.717	0	0.000	1.041	4.717	O	7.738	O	0.000	72	55
3	6.391	0	0.000	1.480	6.391	T	9.710	T	0.000	73	43
4	6.028	0	0.000	1.419	6.028		9.433		0.000	73	43
5	5.744	0	0.000	1.443	5.744	A	9.024	A	0.000	73	47
6	7.024	0	0.000	1.392	7.024	P	11.193	P	0.000	73	32
7	5.282	0	0.000	0.929	5.282	P	9.916	P	0.000	71	34
8	4.241	0	0.000	0.922	4.241	L	8.417	L	0.000	70	49
9	6.955	0	0.000	1.423	6.955	I	10.723	I	0.000	72	39
10	6.386	0	0.000	1.485	6.386	C	9.897	C	0.000	72	44
11	5.435	0	0.000	1.454	5.435	A	8.716	A	0.000	73	49
12	2.935	0	0.000	0.732	2.935	B	5.172	B	0.000	74	67
13	5.053	0	0.000	0.979	5.053	L	7.818	L	0.000	73	60
14	5.958	0	0.000	1.317	5.958	E	9.155	E	0.000	73	53
15	5.095	0	0.000	0.984	5.095		8.351		0.000	72	46
16	6.277	0	0.000	1.420	6.277		9.654		0.000	73	44
17	5.432	0	0.000	1.436	5.432		8.836		0.000	73	47
18	5.089	0	0.000	1.108	5.089		8.564		0.000	74	51
19	4.473	0	0.000	0.928	4.473		7.132		0.000	74	53
20	4.157	0	0.000	0.827	4.157		6.928		0.000	74	57
21	2.470	0	0.000	0.473	2.470		4.119		0.000	74	64
22	2.772	0	0.000	0.396	2.772		4.452		0.000	73	60
23	3.728	0	0.000	0.568	3.728		5.782		0.000	73	60
24	2.894	0	0.000	0.443	2.894		4.348		0.000	74	67
25	2.099	0	0.000	0.384	2.099		3.086		0.000	75	72
26	5.114	0	0.000	0.971	5.114		7.515		0.000	75	59
27	6.074	0	0.000	1.370	6.074		9.697		0.000	75	52
28	5.569	0	0.000	0.985	5.569		8.974		0.000	74	45
29	5.149	0	0.000	0.850	5.149		8.676		0.000	72	49
30	5.678	0	0.000	1.112	5.678		9.045		0.000	73	52
SUM	148.654	-	0.000	31.199	148.654	N.A.	239.486	N.A.	0.000	-	-
AVG	4.955	0	0.000	1.040	4.955	N.A.	7.983	N.A.	0.000	73	51
NBS	Q402	N400	Q400	Q403	Q401		Q410	Q415	Q417	N406	N113

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
SPACE COOLING SUBSYSTEM

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: APRIL,1979

SOLAR/9999-79/04

DAY OF MON.	SPACE COOLING LOAD MILLION BTU	SOLAR FR.CF LOAD FCT	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT ENERGY SAVINGS MILLION BTU	FOSSIL ENERGY SAVINGS MILLION BTU	BLDG DRY BULB TEMP F	AMB TEMP DEG F
1	0.000	0	0.000	0.000	0.000	N	0.000	N	0.000	71	46
2	1.608	0	0.000	0.973	3.105	O	4.408	O	0.000	72	55
3	0.000	0	0.000	0.000	0.000	T	0.000	T	0.000	73	43
4	0.000	0	0.000	0.000	0.000		0.000		0.000	73	43
5	0.000	0	0.000	0.000	0.000	A	0.000	A	0.000	73	47
6	0.000	0	0.000	0.000	0.000	P	0.000	P	0.000	73	32
7	0.000	0	0.000	0.000	0.000	P	0.000	P	0.000	71	34
8	0.001	0	0.000	0.065	0.080	L	0.164	L	0.000	70	49
9	0.000	0	0.000	0.000	0.000	I	0.000	I	0.000	72	39
10	0.000	0	0.000	0.000	0.000	C	0.000	C	0.000	72	44
11	0.000	0	0.000	0.000	0.000	A	0.000	A	0.000	73	49
12	3.727	0	0.000	1.928	6.668	B	10.192	B	0.000	74	67
13	3.598	0	0.000	2.149	7.074	L	9.968	L	0.000	73	60
14	1.493	0	0.000	1.102	3.469	E	4.964	E	0.000	73	53
15	0.000	0	0.000	0.000	0.000		0.000		0.000	72	46
16	0.000	0	0.000	0.000	0.000		0.000		0.000	73	44
17	0.044	0	0.000	0.044	0.159		0.162		0.000	73	47
18	1.226	0	0.000	0.788	2.678		3.727		0.000	74	51
19	1.539	0	0.000	1.051	3.706		5.145		0.000	74	53
20	2.309	0	0.000	1.490	5.142		6.689		0.000	74	57
21	1.768	0	0.000	1.633	5.706		9.111		0.000	74	64
22	1.719	0	0.000	2.108	6.268		10.042		0.000	73	60
23	2.769	0	0.000	2.266	7.217		10.949		0.000	73	60
24	4.626	0	0.000	2.824	9.639		14.424		0.000	74	67
25	6.384	0	0.000	3.388	11.658		17.458		0.000	75	72
26	4.340	0	0.000	2.458	8.459		12.023		0.000	75	59
27	1.272	0	0.000	0.911	3.247		4.427		0.000	75	52
28	0.000	0	0.000	0.000	0.000		0.000		0.000	74	45
29	0.249	0	0.000	0.428	1.733		2.481		0.000	72	49
30	0.909	0	0.000	0.768	2.943		4.120		0.000	73	52
SUM	39.581	-	0.000	26.374	88.950	N.A.	130.456	N.A.	0.000	-	-
AVG	1.319	0	0.000	0.879	2.964	N.A.	4.349	N.A.	0.000	73	51
NBS	Q502	NSCC	Q500	Q503	Q501		Q508	Q512	Q514	N406	N113

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
ENVIRONMENTAL SUMMARY

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: APRIL,1979

SOLAR/9999-79/04

DAY OF MONTH	TOTAL INSOLATION BTU/SQ.FT	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	*INC DIRECTION DEGREES	WIND SPEED M.P.H.
1	167	161	46	46	N	N	N
2	703	428	55	62	C	C	C
3	967	585	43	46	T	T	T
4	124	119	43	46			
5	1086	602	47	48	A	A	A
6	2281	581	32	34	P	P	P
7	1045	608	34	40	P	P	P
8	515	443	49	55	L	L	L
9	144	144	39	34	I	I	I
10	1921	595	44	51	C	C	C
11	499	367	49	49	A	A	A
12	1057	737	67	73	B	B	B
13	241	213	60	64	L	L	L
14	1396	681	53	61	E	E	E
15	565	477	46	47			
16	526	463	44	*			
17	1659	675	47	54			
18	2218	359	51	63			
19	2168	487	53	65			
20	1907	271	57	*			
21	1256	829	64	75			
22	613	552	60	64			
23	766	506	60	*			
24	1309	937	67	*			
25	1704	963	72	77			
26	261	241	59	61			
27	2007	865	52	54			
28	869	545	45	49			
29	1786	754	49	55			
30	1928	608	52	57			
SUM	33686	15788	-	-	-	-	-
AVG	1123	526	51	55	N.A.	N.A.	N.A.
NBS ID	C001		N113			N115	N114

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM

MONTHLY REPORT
THERMODYNAMIC CONVERSION EQUIPMENT

SITE: COLUMBIA GAS, COLUMBUS, OHIO SOLAR/9999-79/04
REPORT PERIOD: APRIL,1979

DAY OF MONTH	EQUIPMENT LOAD MILLION BTU	THERMAL ENERGY INPUT MILLION BTU	OPERATING ENERGY MILLION BTU	ENERGY REJECTED MILLION BTU	COEFFICIENT OF PERFORMANCE (SEE NOTE)
1	0.000	0.000	0.000	0.000	0.000
2	1.608	3.105	0.607	5.439	0.518
3	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000
8	0.001	0.080	0.053	0.000	0.012
9	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000
12	3.727	6.668	1.235	10.839	0.565
13	3.598	7.074	1.378	11.589	0.509
14	1.493	3.469	0.681	5.491	0.430
15	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000
17	0.044	0.159	0.024	0.142	0.279
18	1.226	2.678	0.487	3.474	0.458
19	1.539	3.706	0.665	5.064	0.415
20	2.309	5.142	0.991	6.874	0.449
21	1.768	5.706	1.199	8.473	0.310
22	1.719	6.268	1.612	8.284	0.274
23	2.769	7.217	1.574	10.829	0.384
24	4.626	9.639	1.777	14.409	0.480
25	6.384	11.658	1.899	19.320	0.548
26	4.340	8.459	1.458	13.372	0.513
27	1.272	3.247	0.576	4.260	0.394
28	0.000	0.000	0.000	0.000	0.000
29	0.249	1.733	0.327	1.885	0.144
30	0.909	2.943	0.498	3.995	0.309
SUM	39.581	88.950	17.045	133.741	0.446
AVG	1.319	2.965	0.568	4.458	0.015

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.
NOTE:

SOLAR HEATING AND COOLING DEMONSTRATION PROGRAM
MONTHLY REPORT
EXTRA LOAD SUBSYSTEM

SITE: COLUMBIA GAS, COLUMBUS, OHIO
REPORT PERIOD: APRIL,1979

SOLAR/9999-79/04

DAY OF MONTH	LOAD MILLION BTU	SOLAR FRACTION OF LOAD PERCENT	SOLAR ENERGY USED MILLION BTU	OPER ENERGY MILLION BTU	AUX THERMAL USED MILLION BTU	AUX ELECT FUEL MILLION BTU	AUX FOSSIL FUEL MILLION BTU	ELECT ENERGY SAVINGS MILLION BTU	FOSSIL ENERGY SAVINGS MILLION BTU
1	0.135	0	0.000	0.990	0.135	N	7.415	N	0.000
2	5.276	0	0.000	2.015	5.276	O	12.146	O	0.000
3	1.587	0	0.000	1.450	1.587	T	9.710	T	0.000
4	2.380	0	0.000	1.419	2.380		9.433		0.000
5	1.422	0	0.000	1.443	1.422	A	9.024	A	0.000
6	3.851	0	0.000	1.392	3.851	P	11.193	P	0.000
7	1.823	0	0.000	0.929	1.823	P	9.916	P	0.000
8	1.113	0	0.000	0.987	1.113	L	8.582	L	0.000
9	1.820	0	0.000	1.423	1.820	I	10.723	I	0.000
10	1.121	0	0.000	1.455	1.121	C	9.897	C	0.000
11	0.769	0	0.000	1.454	0.769	A	8.716	A	0.000
12	9.682	0	0.000	2.659	9.682	E	15.364	E	0.000
13	11.838	0	0.000	3.127	11.838	L	17.786	L	0.000
14	6.419	0	0.000	2.419	6.419	E	14.120	E	0.000
15	0.161	0	0.000	0.984	0.161		8.351		0.000
16	1.577	0	0.000	1.420	1.577		9.654		0.000
17	1.063	0	0.000	1.480	1.063		8.998		0.000
18	4.993	0	0.000	1.896	4.993		12.291		0.000
19	6.125	0	0.000	1.979	6.125		12.277		0.000
20	7.666	0	0.000	2.317	7.666		13.616		0.000
21	8.122	0	0.000	2.106	8.122		13.231		0.000
22	10.403	0	0.000	2.504	10.403		14.494		0.000
23	11.986	0	0.000	2.834	11.986		16.731		0.000
24	12.430	0	0.000	3.267	12.430		18.772		0.000
25	10.803	0	0.000	3.772	10.803		20.544		0.000
26	14.391	0	0.000	3.429	14.391		19.539		0.000
27	10.298	0	0.000	2.281	10.298		14.125		0.000
28	7.855	0	0.000	0.985	7.855		8.974		0.000
29	7.760	0	0.000	1.278	7.760		11.158		0.000
30	9.050	0	0.000	1.880	9.050		13.165		0.000
SUM	173.917	-	0.000	57.573	173.917	N.A.	369.941	N.A.	0.000
AVG	5.797	0	0.000	1.919	5.797	N.A.	12.331	N.A.	0.000

* DENOTES UNAVAILABLE DATA.
@ DENOTES NULL DATA.
N.A. DENOTES NOT APPLICABLE DATA.

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